Reversible Fuel Cells for Long Duration Storage

Thomas Zawodzinski, University of TN-Knoxville

Team Members: Peroxygen Systems Inc

Project Vision

Not your grandfather's Fuel Cell!

Peroxide as a Product enables high efficiency, low cost

Virtually no self-discharge over long periods!

Total project cost:	$1.5M
Length	24 mo.

~~Reversible Fuel Cells~~

Peroxide Enabled Long Duration Electrochemical Energy Storage (PELoDEES)

Thomas Zawodzinski, University of Tennessee-Knoxville

Team Members: Peroxygen Systems Inc, Electrosynthesis Inc

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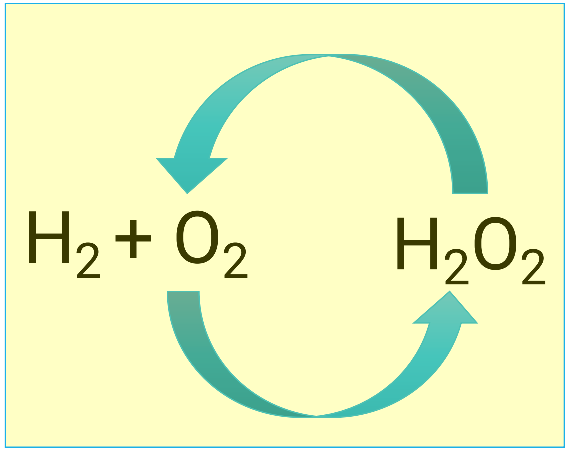
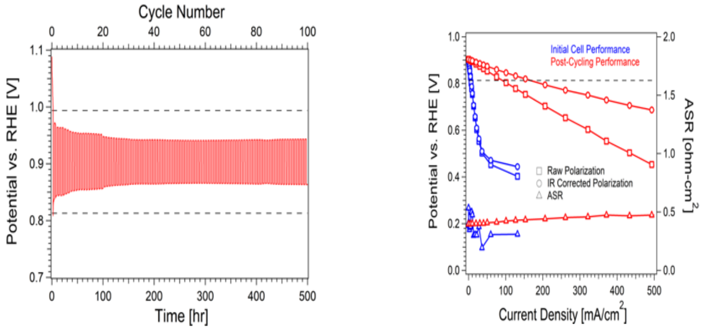
PELoDEES: A Path to Efficient Cycling to Leverage H_2 Storage Innovations in Catalysts-Cell-Stack-System



Reversible Fuel Cell (with a twist)



Electrode performance

Hydrogen and Oxygen in charged state—cheap, easily available, near zero self-discharge!

BUT

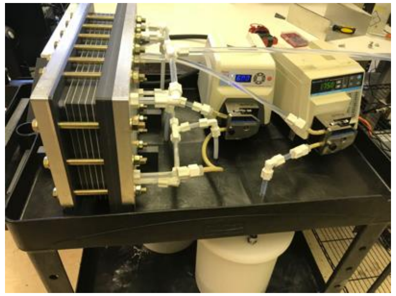
Conventional fuel cells are inefficient with expensive catalysts.

ENTER PELoDEES

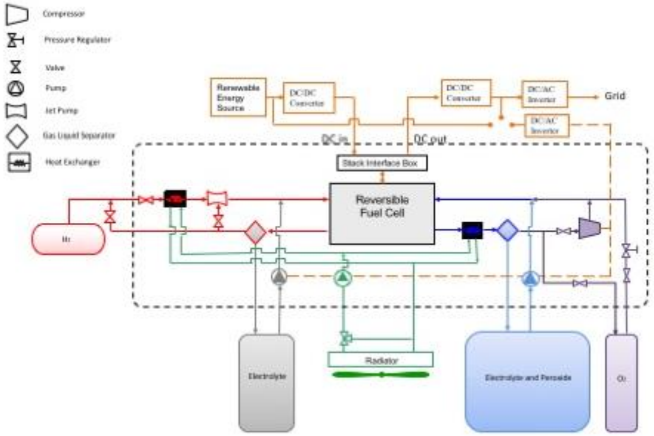
We discovered cheap catalysts to produce peroxide with *electrochemical reversibility*

High efficiency

Possible long-term storage with extremely low self-discharge: in charged state we store H_2 and O_2



Stack at PSI



CHANGING WHAT'S POSSIBLE

The Team

- **Tom Zawodzinski, PI:** 30 years experience as a leader in electrochemical S&T—fuel cells, batteries, flow batteries, etc.
- **UTK team**—senior scientists: Shane Foister (chemical synthesis), Gabriel Goenaga (testing), Ramez Elgammal (material development)
- **PSI**: small (but growing) company commercializing peroxide catalyst technology
- **New partner (projected): Electrosynthesis Co.--**~40 years experience testing and scaling electrochemical technology.
- **Unique consulting and 'ecosystem' infrastructure**: Former GM fuel cell stack and system design for manufacturing doing design and TEA; small polymer company makes batches of materials; coating at scale at Kodak

Project Objectives

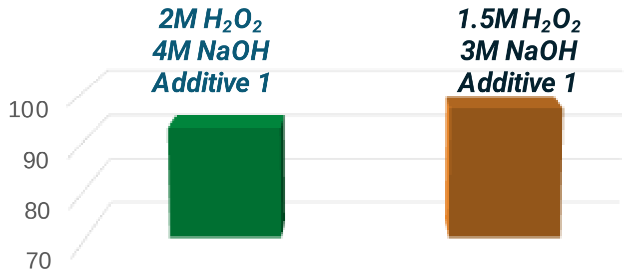
- Technical Risks
  - 1. Catalyst performance on hydrogen electrode.
  - 2. Managing two-phase flow in stacks.
  - 3. For ‘one-stack’ design, achieving proper balance of material properties under reverse polarity.
- Prototype Size: In this phase of the work, we aim for proof of concept on 100 cm^2 cells and possibly a short stack.
- Scaling: The larger cell design is essentially a modular array of the 100 cm^2 cells. We have previously developed stacks using this concept. System design is relatively straightforward.

Results: Long term stability

Peroxide stability

- Concern based on literature values of decay rate in alkaline solution
- More recent additive package shows stability of ~97% over 10 hours
- TEA shows minimal cost from 'make-up'
- Stability in fully charged state is essentially unlimited (self-discharge minimal)
  - This enables long duration between cycles

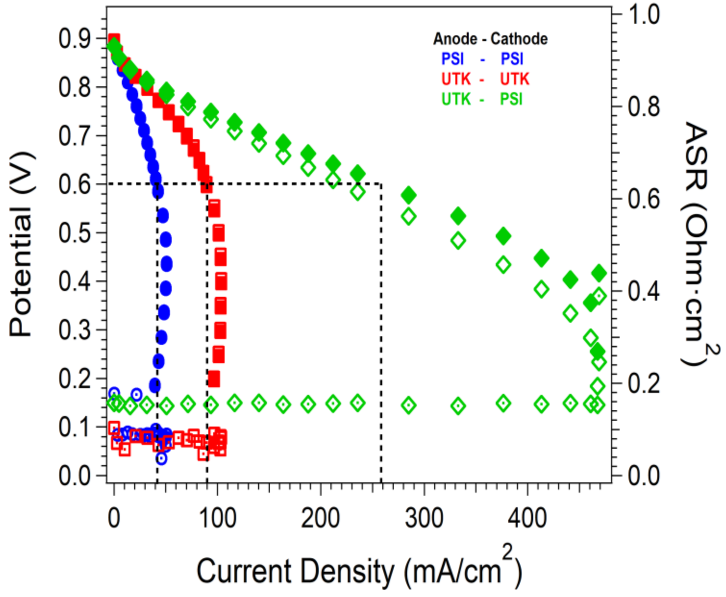
Peroxide Stability, 30 °C, 10 hours

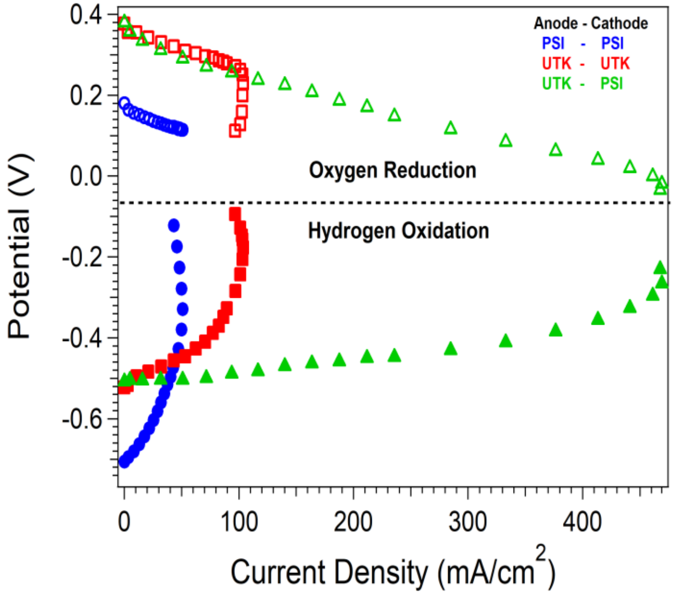


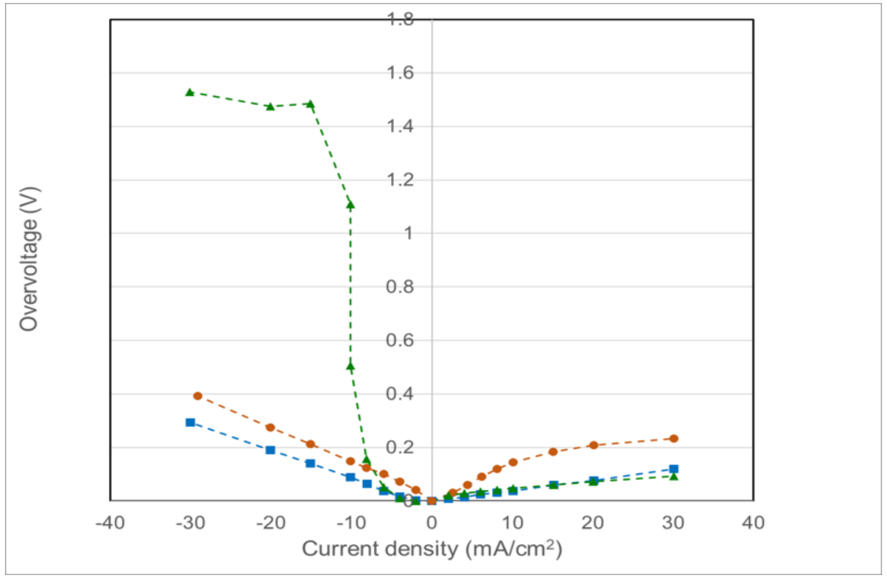
average	92.9%	96.8%
std. dev.	0.3%	0.4%

Results: Performance in ‘single cell’ systems

- Scaled-up to 100 cm^2 cells; results match those in 5 cm^2 cells
- Polarization curves (left) indicated that two different electrode constructs (labeled UTK and PSI) needed for positive and negative electrodes
- Hydrogen polarization curve indicate promising reversibility (hydrogen electrode shown) for single cell operation



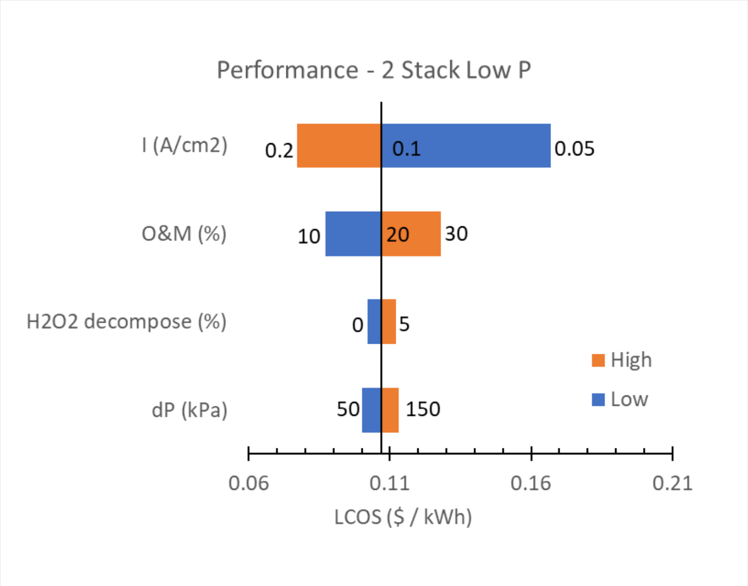


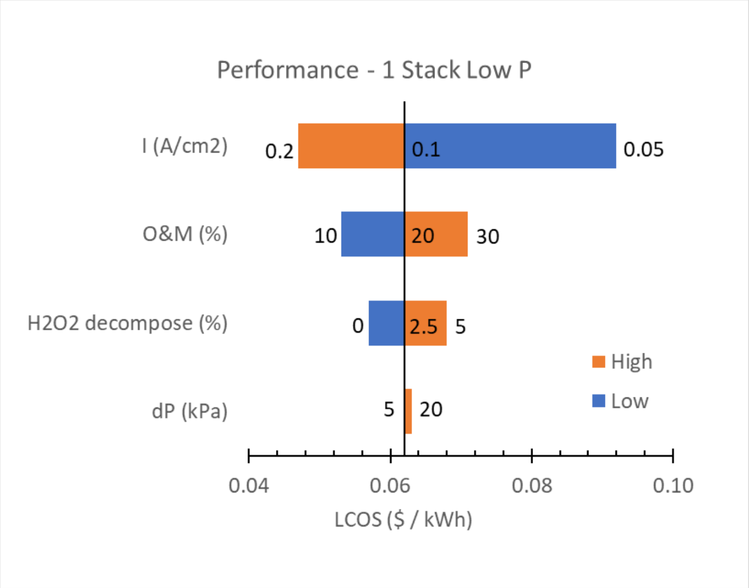


- Performance targets (cell current density) can be met or exceeded but some difficulty with catalyst reproducibility.
- Cycling is beginning at this time.

Results: Cost

- Cost estimates (all-in) show clear paths to meeting cost targets
  - Enabled by low cost materials, high efficiency
- Many configurations, ways of using system possible
- *Solar farm storage use case:*





10 MW system had an LCOS of **0.039 $/kWhr***. **Based on recent results, we have small gains on this figure.**

*Operating at 0.2 A/cm^2 (1.1 V charge, 0.71 V discharge) with 10 hr discharge, 9.75 hr charge and 4.25 hr idle with 2.5% peroxide decomposition and H_2 and O_2 makeup, without labor or DC-DC boost,

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Challenges and Potential Partnerships

- Known issues that we attacked
  - Proving sufficient peroxide stability and cost of mitigation. *Solved*
  - Stack design issues. *We have functioning solutions.*
  - Getting to a system understanding, supply chain. *Baked into project.*

- Known unknowns: Coulombic efficiency issues (catalysts).

- Unknown unknowns: (Accelerating development and/or deployment) Cycling performance; Solving stack design challenges and getting to system implementation; Identification of long-duration use cases. Teaming with integrators.

- Partnerships: Eventually plan to form a joint-venture company for next stage of development beyond next BP.' **Options open.**

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Technology-to-Market

- **Our ultimate goal**

Provide inexpensive and flexible LDS based on hydrogen and oxygen, including a whole-system concept and paths to manufactured system.

- **Timeline**

We are still fairly early stage in development; hardware design is modular and all work is directly connected to system considerations.

- **Getting Beyond the Current Status**

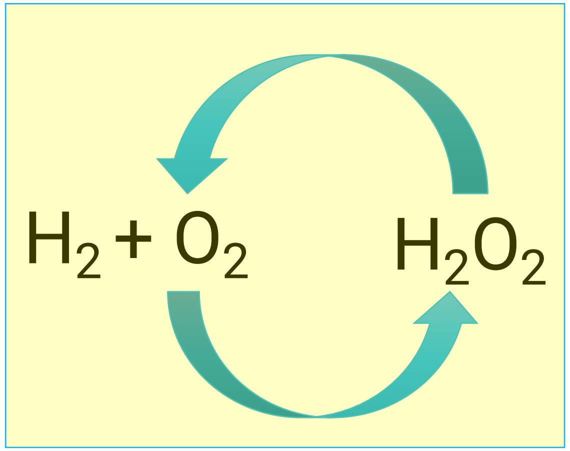
Some teaming with system developers/integrators. Improved catalyst synthesis. An end to COVID-based restrictions (to allow some planned material scale-up)!

Possible commercial applications and market entry options:

Applications: transportable LDS for disaster response and related. Possibilities for seasonal H_2 storage.

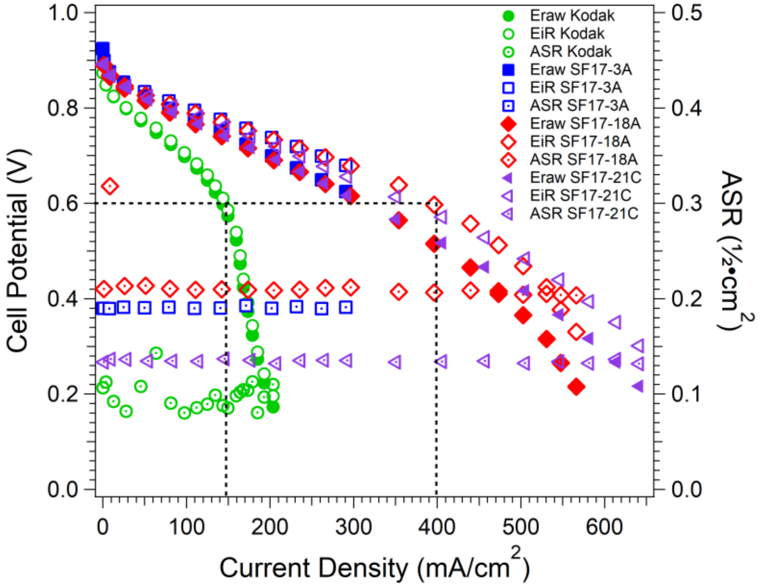
Market Entry Approach: Options open; PSI is key partner now but spin-off likely.

Summary: PELoDEES
Innovations in Catalysts-Cell-Stack-System



Reversible Fuel Cell (with a twist)

Good performance



Inexpensive core technology
High efficiency

Possible long-term storage with extremely low self-discharge: in charged state we store H_2 and O_2

Status

- Stack-sized cell modules built and tested; material, catalyst issues being addressed.
- Cycling of cells imminent.
- System design in hand. Next phase would include ‘brassboard’ system.

Possible commercial applications and early options: transportable LDS for disaster response and related. Possibilities for seasonal H_2 storage.

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https://arpa-e.energy.gov

Thanks to Scott, Max and Sean for helpful discussions throughout.